Aus dem Departement für Nutztiere, Klinik für Wiederkäuer
(Direktor: Prof. Dr. Ueli Braun)
der Vetsuisse-Fakultät
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# Difference in the length of the metacarpal and metatarsal condyles in calves and cows

INAUGURAL - DISSERTATION

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**Saidou Nacambo**

Tierarzt von Ouahigouya, Burkina Faso

Genehmigt auf Antrag von
PD. Dr. Karl Nuss, Referent
PD. Dr. Christoph J. Lischer, Korreferent

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Dedicated to my parents

## Index

**Difference in the length of the metacarpal and metatarsal condyles in calves and cows.**

## 1. Summary / Zusammenfassung

Key words: Calves – cows – metacarpal and metatarsal condyles – difference in length – claw size

**Objective**: The lengths of the lateral and medial condyles of the metacarpal and metatarsal condyles were measured and compared in 42 calves and 10 cows. In addition, various measurements of the claws were obtained and compared to the measurements of the corresponding condyles in 12 of these calves.

**Materials and methods**: The lower legs and feet of 42 calves of various breeds, which were euthanased for reasons unrelated to the study, were used. The soft tissues were removed from the metacarpal and metatarsal bones, which were sawed in half in the frontal plane. The length of the bone including the epiphysis, and the length of the condyles, measured in three different regions, were measured on the cut surface of the dorsal half of the bone. In addition, in the cannon bones of 10 cows, the difference in length of the condyles was measured. The measurements were made manually using precision instruments and a computer software program. The dorsal length of the wall of the claw, the diagonal length of the claw and the width of the claw at the end of the axial wall and at the widest part were also measured in 12 of the calves.

**Results**: There was a significant difference between the lengths of the metacarpal and metatarsal bones; the metacarpal bones were almost exactly 2 cm shorter than the metatarsal bones. In both the metacarpal and metatarsal bones, the lateral aspects of the bones and the lateral condyles were, on average, longer than the medial ones. The difference in the condylar length was more pronounced in the metatarsal bones than the metacarpal bones. In both the front and hind limbs, the lateral claw was wider than the medial claw whereas the length of the dorsal wall of

the medial claw was greater than that of the lateral claw. There was no significant difference between measurements obtained manually and those obtained digitally.

**Conclusions**: There was a constant anatomical difference between the medial and lateral condyles of the metacarpal and metatarsal bones. In the majority of newborn and young calves as well as cows the lateral condyle of the metacarpal and particularly the metatarsal bones was longer than the medial condyle. In a few cases, the condyles were the same length and rarely was the medial condyle longer than the lateral. In calves, the sole of the lateral claw was wider than that of the medial claw but the medial claw had a longer dorsal wall than the lateral claw. These anatomical differences may explain why the lateral and medial claws develop differently and the predisposition of the lateral claw of the hind limb to disease.

## Zusammenfassung

Schlüsselwörter: Kalb - Kuh - Kondylen der Ossa metacarpalia und metatarsalia - Längendifferenz - Klauengrösse

**Ziel:** Die Länge des lateralen und medialen Kondylus der Ossa metacarpalia und metatarsalia wurden zur Feststellung eines Längenunterschiedes bei 42 Kälbern und 10 Kühen gemessen und verglichen. Zusätzlich wurden Klauenmasse bei 12 dieser Kälber erhoben und mit der Länge der Kondylen in Beziehung gesetzt.

**Material und Methode:** Die Füsse von 42 Kälbern unterschiedlicher Rassen, die in der Klinik starben oder aus Gründen, die nicht mit der Studie zusammenhingen, eingeschläfert werden mussten, wurden gesammelt. Die präparierten Ossa metacarpalia und metatarsalia wurden transversal in zwei gleich grosse Hälften zersägt. An der Schnittfläche der dorsalen Hälften wurden die Länge des Knochens einschliesslich der Epiphyse gemessen sowie drei Längenmasse für die Kondylen erhoben. Die Messungen wurden manuell mit Präzisionsinstrumenten und digital mit Hilfe einer Computersoftware durchgeführt. Zusätzlich wurden vier Variablen an den Klauen, nämlich die Dorsalwandlänge, die diagonale Klauenlänge, die Klauenbreite im Bereich des Endes der axialen Wand und die Klauenbreite am Ballen, erhoben.

**Ergebnisse:** Es bestand ein beträchtlicher Längenunterschied zwischen den Ossa metacarpalia und metatarsalia. Die Knochen der Schultergliedmassen waren um fast genau 2 cm kürzer als die der Beckengliedmassen. Die laterale Knochenseite und die lateralen Kondylen waren im Mittelwert signifikant länger als die medialen, sowohl an den Vorder- als auch an den Hintergliedmassen. Dieser Unterschied in der Epiphysenlänge war an den Beckengliedmassen häufiger und stärker ausgeprägt als an den Schultergliedmassen. Die lateralen Klauen waren regelmässig breiter als die medialen, sowohl an den Vorder- als auch an den Beckengliedmassen. Die Dorsalwandlänge der medialen Klauen war jedoch grösser als die der lateralen. Manuelle und digitale Messungen unterschieden sich statistisch gesehen nicht.

**Schlussfolgerungen**: Es existiert ein anatomischer Unterschied in der Länge der Metakarpal- und besonders der Metatarsalkondylen schon bei neugeborenen und sehr jungen Kälbern, und auch bei Kühen. Der laterale Kondylus ist in den meisten Fällen länger als der mediale, weniger oft gleich lang, und selten ist der mediale länger. Die lateralen Klauen weisen bei Kälbern auch eine grössere Sohlenbreite auf. Allerdings haben die medialen Klauen die grössere Dorsalwandlänge. Diese anatomischen Gegebenheiten könnten zu der Erklärung beitragen, warum die Klauen sich unterschiedlich entwickeln und die lateralen Klauen der Beckengliedmassen für Erkrankungen prädisponiert sind.

## 2. Introduction

In many dairy herds, claw diseases represent a substantial health problem and often lead to decreased production, infertility and culling. Predisposing factors for claw disease include nutritional imbalances, metabolic diseases, housing inadequacies, infection and congenital abnormalities such as poor limb and claw conformation.

Approximately 84 per cent of claw diseases occur in the hind claws, and of these, 85 per cent affect the lateral claw (Russell and others 1982). The lateral claws of the hind limbs are more commonly affected by sole ulcers and are more severely affected by laminitis than the medial claws (Smits and others 1992). Although this has been known and discussed for almost 100 years, the reasons are not completely clear.

Kehler and Gerwing (2004) showed that on average, 63 per cent of the body weight is distributed to the sole of the lateral claw and 37 per cent to the medial in cows with untrimmed claws. After functional trimming, the distribution of weight was almost even between the two claws. However, four months later, the lateral claw bore markedly more weight than the medial claw and six weeks after that, the distribution of weight had returned to that of untrimmed claws (Kehler and Gerwing 2004). In hind feet from slaughtered cows that were trimmed to equal sole thickness in both claws, the lateral claw extended slightly further distally than the medial claw (Paulus and Nuss 2002). The authors hypothesised that the difference was due to a difference in length of the lateral and medial metatarsal condyles.

The aim of the present study was to measure and compare the medial and lateral condyles of the metatarsal and metacarpal bones in cows and calves.

A further goal was to make specific claw measurements in calves to determine the differences between the medial and lateral claws, and to relate them to differences between the medial and lateral condyles.

The following study has been submitted to the Journal of Veterinary Medicine A for publication. An abstract and a presentation were given at the 13th International Symposium on Diseases of the Bovine Digits and 5th Conference on Lameness in Ruminants, Slovenia 2004 (Nacambo et al., 2004).

## 3. Literature Review

### 3.1 Anatomy of the Os metacarpale

In cattle the fetal metacarpal and metatarsal bones III and IV fuse to form the metacarpal and metatarsal bone (cannon bone). The metacarpal bone has a convex facies dorsalis and a flat facies palmaris with a sulcus longitudinalis dorsalis, respectively palmaris. At the distal end there is a channel for vessels, the canalis metacarpi distalis.

The medial and lateral condyles, which support digits III and IV, respectively, remain separate (Frewein and others 1992).The separated origin of the metacarpal bones can also be seen in the marrow cavity, which is split up by an incomplete partition wall. This wall degenerates with age and therefore often lacks proximally. The articular surface of each of the two trochleae is divided by a sagittal crest into an narrow part, which goes further distal and is more axial, and into a second part, which is broader and more abaxial.The part of the bone which is formed by the Os metacarpale III is broader proximally. The trochleae of the two main digits are divided by the incisura intertrochlearis. The metacarpus shows a slight torsion around the longitudinal axis, which is seen as a pronation.

### 3.2 Anatomy of the Os metatarsale

The Os metatarsale III and IV of the hind limb are fused to one metatarsal bone analogous to the front limb. On the front limb the cannon bone shows a more quadratic diameter whereas it is more oval on the hind limb.

The medial part of the metatarsal bone is slightly bigger and there is a sulcus in between the two parts. The difference in size is less evident than with the metacarpal bone.

The Os metatarsale III and IV is longer than the Os metacarpale III and IV. The ratio is approximately eight to seven. Moreover, the Os metatarsale is thinner. The distal end has also here two separated trochleae, one sagittal crest each (Frewein et al. 1992).

In a study of metacarpal and metatarsal bones from a small number of bovine fetuses, Petersen (1921) determined that the lateral condyle was longer than the medial.

### 3.3 Claw horn anatomy

The surface of the sole of newborn calves shows a soft, elastic, water containing cushion of the horn, the Eponychium. It is 10 to 20 mm long. The process of the sole of healthy calves has dried out and is worn out after 4 days and cannot be seen any longer. Nickel et al. (1992) described a repellence of the Eponychium 3 to 5 hours after birth; latest after one day. The surface of the sole is also described elastic by Pentea and Ganta (1998). The transition between sole to heel and forms a relatively constant point.

The wall of the claw is coated by an epidermal structure, which is often already missing at the newborn. This epidermal layer forms a structure which overlays partly the claw from the coronet. Pentea and Ganta (1998) also observed, that in newborns the horn was covered by transparent and soft periople. At the age of two months this layer was less transparent and has a striped appearance.

The claw wall which is formed intrauterine is smooth and flat. Schultze (1909)

described a formation of circles in the claw wall. He thought this was due to the horn which was formed after birth. Especially the first ripple which was parallel to the coronary groove could be well distinguished. The origin of this distinction was explained by the drying out of the originally soft periople after birth. For the first time, these circles could be distinguished on the fifth day after partum. The author hypothesised, that the animals' age could be estimated thanks to this structure.
The distance of the circle from the coronary border was the same as the length of the formed horn after birth. Schultze (1909) additionally described a physiological formation of circles due to nutritional effects such as starving or food change which could be observed similarly during pregnancy or pasturing in cows.
In male calves, Greenough (1990) observed a formation of horn, parallel to the coronary groove on the surface outside the horn wall. Some animals showed a different quality of the distal and proximal of this ripple. Since the different quality did not show in all the animals he presumed, that some calves were more and others less influenced by intensive feeding. This distance to the coronary groove could mean, that the ripple was formed because of a negative influence during the time when there was a change to very energetic food. He concluded, that the structure was due to an interruption of horn production in these animals (Greenough 1990).

## 4. Material and methods

It was our particular interest to check and to evaluate the length of the metacarpal and metatarsal condyles for the reason that, an asymmetry in the calves cannon bones condyles may the site of the claw lesions. The questions were then, whether this anatomical difference occurs in cows, and in young calves? Would this difference be consistent? Would there be a link between the condyle length and the claws size? Our hypothesis was, that measurements of the calves cannon bones condyles length may show one of the underlying causes which was the underlying cause of lameness in adult cows under current housing conditions.

Therefore, we started our investigation in calves younger than two months.

The main objectives of the study were to establish:

- a comparison between the length of the medial and lateral metacarpal and metatarsal condyles,
- a measure of the difference in size between the medial and lateral claw of these calves,
- a probable correlation of the claw size with the condyles' length.

The large metacarpal and metatarsal bones of 42 calves and 10 cows, which died or were euthanized for reasons unrelated to the study, were used. The animals were of various breeds, and there were 20 female and 20 male calves. The gender was unknown in two calves. The female calves were an average of 24.2 days old and the male calves an average of 18.1 days. The mean age of the cows was 44.5 months.

### 4.1 Bone measurements

From all feet, the skin and soft tissues were removed and the bones were sawed with a band saw (Figure 1) in half in the frontal plane yielding a dorsal and a palmar/plantar portion. The manual measurements were done with a ruler. For the digital measurements, the bones were photographed with a digital camera from a distance of 60 cm. In every picture, a ruler placed at the level of the cut surface of the bone served as a reference for the digital measurements.

Figure1: Band saw used to cut the cannon bones into equal parts.

**Preliminary measurements**: In a preliminary trial, four different measuring techniques were used for the metatarsal and metacarpal bones of one calf. Measurements were obtained from:

- Radiographs,
- Paper print of the bones,
- The bones with a ruler
- Digital photographs of the bones, by digital measurements.

All the variables were measured six times for each method and the results were compared using the coefficient of variation. Radiographs (Figure 2) were least reliable because the contours of the bones and growth plates were poorly defined and thus, this method was abandoned.

The paper prints were not usable either: the fresh preparations printed spongy lines and discolorations on the paper, so the lines could not be clearly defined. Manual measurements of the bones using a ruler and digital measurements (Software Metron PX$^{TM}$, Eponatech, Creston, California, USA) using photographs were the two methods used. Measurements were made from digital pictures, with equal distance, and a ruler situated on the level of the cut surface of the bone as a reference value. The manual and digital measurements were made with an accuracy of 1 mm and 0.1 mm, respectively. The manual measurements served as the gold standard and were compared with the results of the digital measurements (Figure 3).

Figure 2: Radiograph showing the epiphyseal lines of a metatarsus, which are poorly defined. Also note that the epiphyseal line is located more proximal on the medial side (arrow). A difference in length between the medial and the lateral metatarsal condyles is also evident. The difference continues down to the pedal bone.

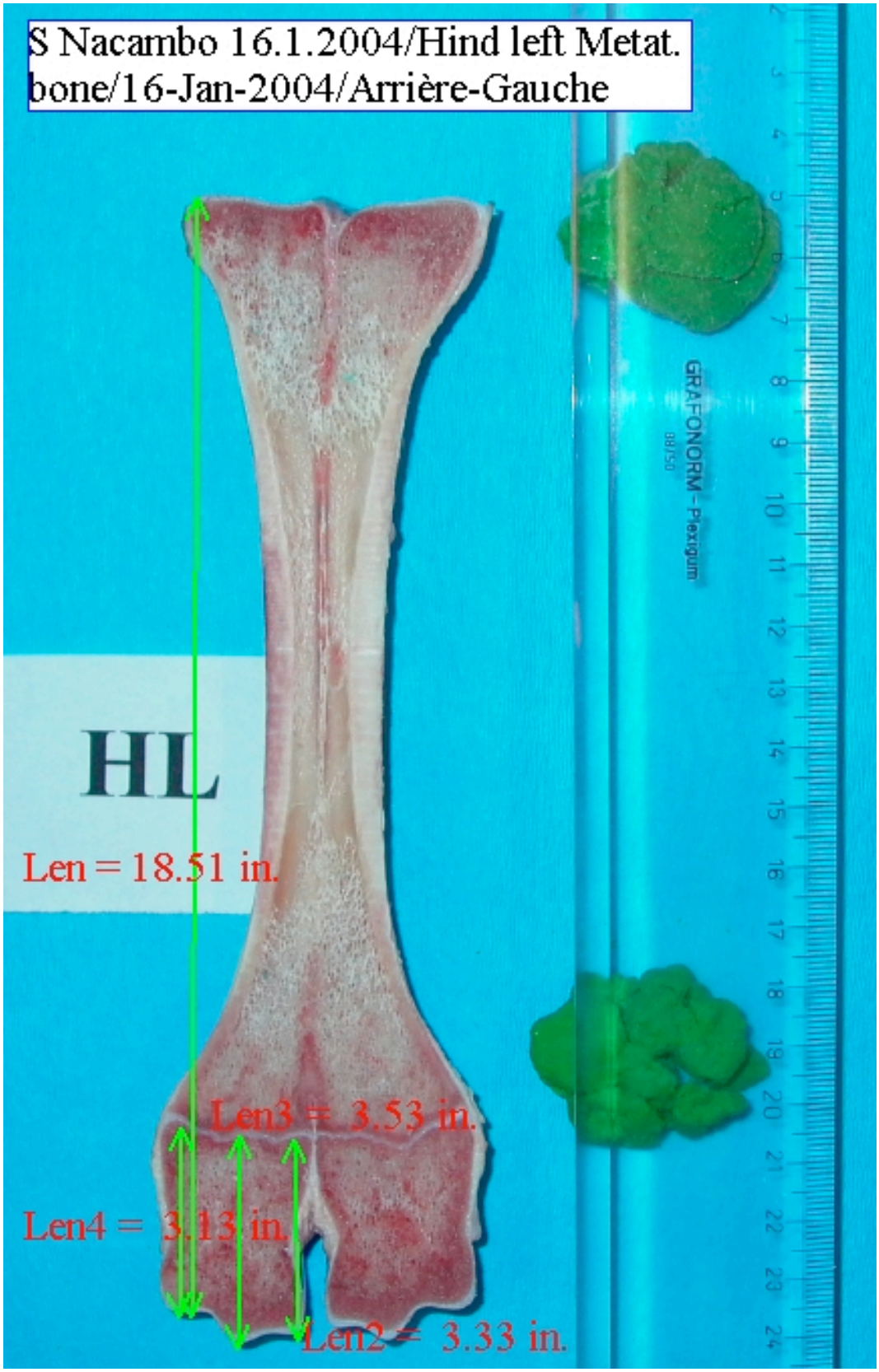


Figure 3: Measurements of digital photograph with the software Metron PX (description see text).

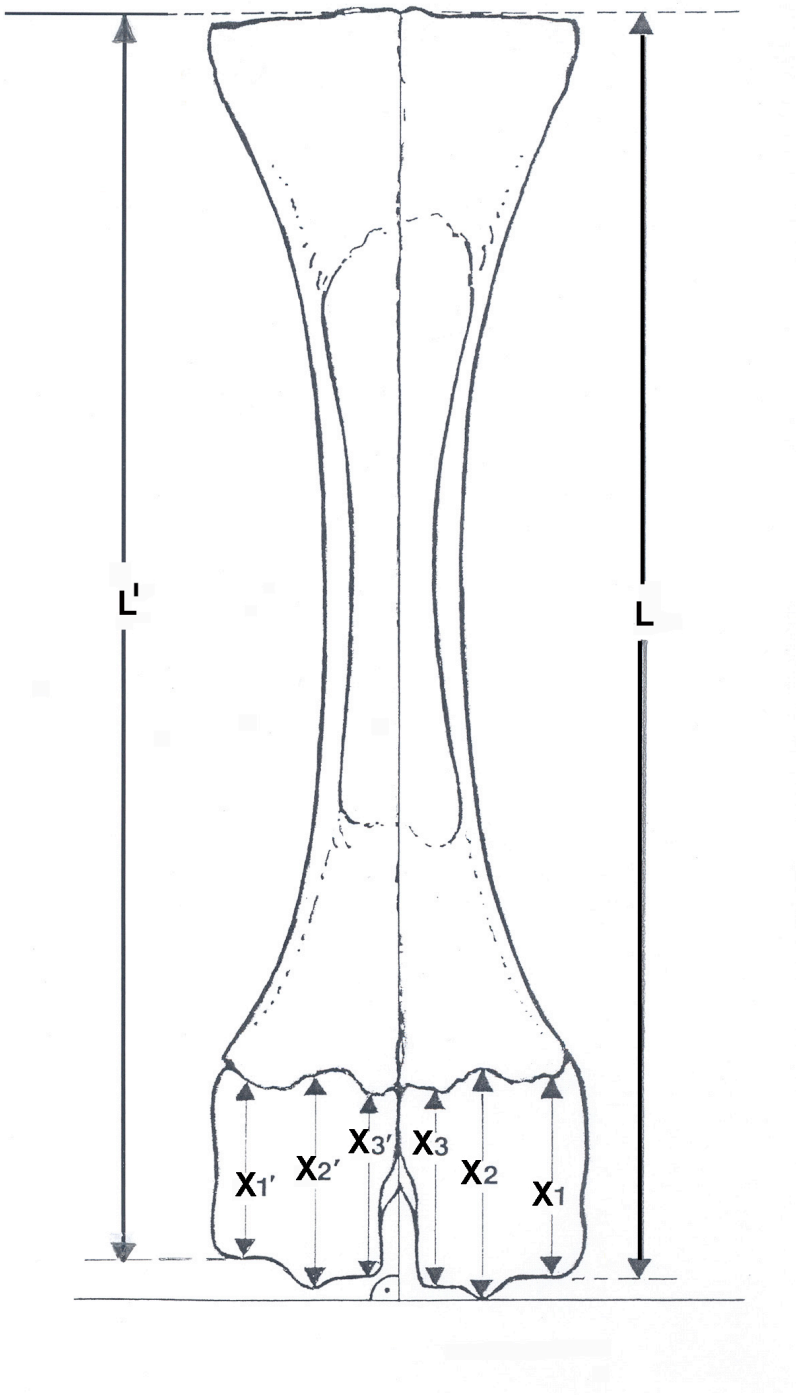


Figure 4: Diagram of the measurements of the lateral (L, X1, X2 and X3) and the medial aspects (L', X1', X2' and X3') of calves bones.

L = distance from the lateral end of the metatarsal bone to the abaxial border of the lateral condyle; X1=distance from the lateral border of the physis to the abaxial end of the lateral condyle; X2=distance from the physis to the distal end of the condylar ridge; X3=distance from the axial aspect of the physis to the axial end of the lateral condyle.
The corresponding measurements were also made on the medial aspect of the bone (L', X1', X2', X3').

Four measurements, each for the medial and lateral sides, were made on the cut surface of the dorsal half of the calves' bones (Figure 4).

The variable L was the distance from the lateral proximal end of the metatarsal bone to the abaxial border of the lateral condyle. X1 was the distance from the lateral border of the growth plate to the abaxial end of the lateral condyle, X2 was the distance from the physis to the distal end of the condylar ridge and X3 was the distance from the axial aspect of the physis to the axial end of the lateral condyle. L´, X1´, X2´and X3´ represented the analogous measurements of the medial side of the bone.

Additionally, the cannon bones of 10 cows older than 3 years were evaluated (Figure 5). In the 40 bones , the difference in the length of the medial and lateral condyles was measured using a line drawn at the level of the condylar ridges, at right angles to the long axis of the bone (Figure 5). For these cows, only the difference in length of the sagittal condylar ridge (X2/X2´) was measured because the growth plate could not be clearly identified. The difference between the lateral and medial metatarsal and metacarpal condyles was measured manually and digitally (Figure 5).


Figure 5: A cow's metacarpal and metatarsal condyles, measured from digital photographs. In cows, only the difference of the condyle lengths was measured (see text).

### 4.2 Claw measurements

In addition, the following claw measurements were carried out in all eight claws of 12 of the 42 calves that were less than 1 week of age: the length of the dorsal wall (DWL), the diagonal length of the claw (CL) and the width of the claw at two areas (CW1 and CW2; Figure 6).

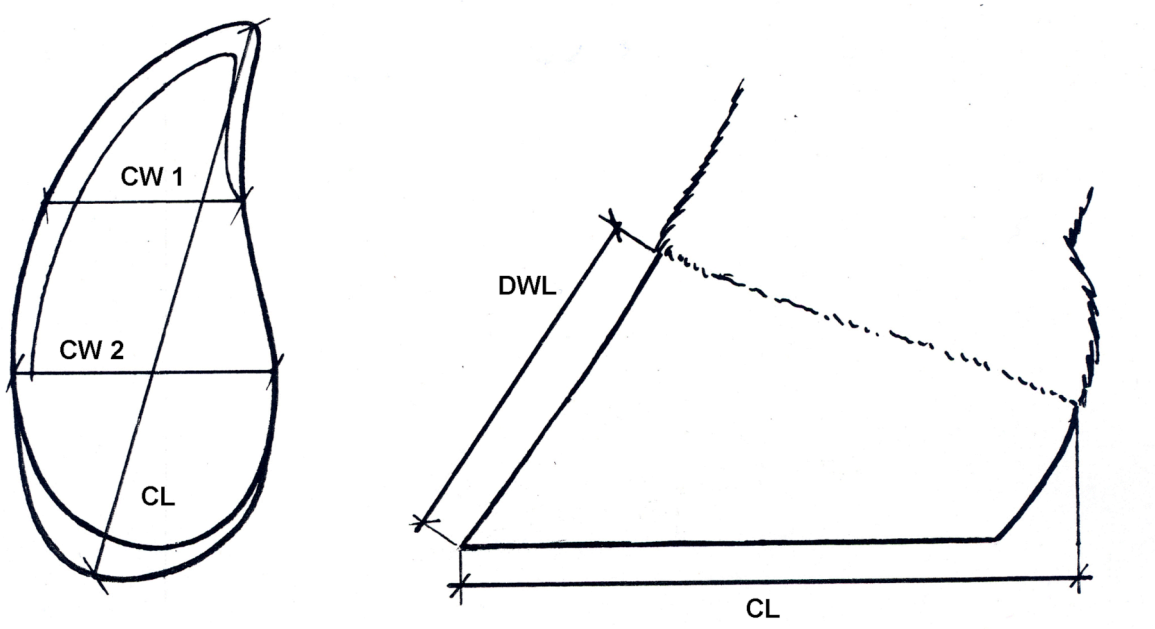


Figure 6: Diagrams of claw measurements.

CW1 = Claw Width at the end of the axial wall; CW2 = Claw Width at the widest part of the sole. ; CL = Diagonal Claw Length; DWL = Dorsal Wall Length.

The measurements were made using a calliper with an accuracy of 0.1mm. The claws were not trimmed. The dorsal wall length was measured from the distal end of the dorsal wall to the highest point of the coronary band of the dorsal part.
The diagonal claw length was taken from the solear surface, from the axial distal end of the claw to the abaxial farest point of the coronary band in the palmar/plantar side. The claw width 1 was measured from the abaxial sole surface to the end of the axial wall. The claw width 2 was obtained by measuring the sole at its widest part.

### 4.3 Statistical analysis

A statistical software Programme (Stat View 5.0, SAS Institute Inc., Cary, North Carolina, USA) was used for data analysis. The coefficient of variation was calculated by dividing the mean by the standard deviation of the mean.

Accuracy and repeatability of measurements were considered excellent if the coefficient of Variation was smaller than 0.05. The Spearman rank-order correlation coefficient was used to compare manual and digital measurements. The Student *t*-test and analysis of variance for repeated measures were used to compare means. A P-value of $< 0.05$ was considered significant.

## 5. Results

### 5.1 Bone measurements

There were no significant differences between the manual and digital measurements, but the coefficient of variation was smaller in the manual measurement than in the digital. Therefore the results of the manual measurements are presented. There were no significant differences between the bone and the claw measurements of the contralateral limbs. The metatarsal bones (measurement L and L´) were almost 2 cm longer than the metacarpal bones ($p < 0.01$). A ratio of 1:1.125 for the lengths of the metacarpal and metatarsal bones could be calculated. The lateral side of the metatarsal bone (L) was longer ($p < 0.01$) than the medial side (L'); this difference was seen in 83 of the 84 bones. A smaller but still significant difference ($p < 0.05$) was seen in the metacarpal bones; in 44 bones, the lateral side was longer, in 23 the medial side and in 17, both sides were the same.

The means for the measurements X1, X2 and X3 were significantly larger than X1´, X2´ and X3´ in the metatarsal bones. In some cases the measurements of the medial condyles were the same as those of the lateral condyles while in others, particularly in the metacarpal bone, they were larger (Tables 1 and 2).

Table 1: Means and standard errors of the lengths of the metacarpal and metatarsal bones (L and L´) of 42 calves in centimetres (standard errors in parenthesis), and lengths of the condyles (X1 to X3 and X1´ to X3´)* of these bones. *Obtained by manual measurement.

| | Front | | | | Hind | | | |
|---|---|---|---|---|---|---|---|---|
| | Left | | Right | | Left | | Right | |
| | **lateral** | **medial** | **lateral** | **medial** | **lateral** | **medial** | **lateral** | **medial** |
| **L/L´** | 16,77 (.148) | 16,71 (.154) | 16,78 (.146) | 16,72 (.150) | 18,76 (.161) | 18,41 (.166) | 18,80 (.159) | 18,42 (.159) |
| **X1/X1´** | 3.2 (.053) | 3.3 (.048) | 3.2 (.041) | 3.2 (.042) | 3.2 (.056) | 3.0 (.056) | 3.2 (.056) | 3.0 (.044) |
| **X2/X2´** | 3.4 (.037) | 3.3 (.038) | 3.4 (.038) | 3.3 (.035) | 3.4 (.037) | 3.3 (.038) | 3.4 (.040) | 3.3 (.038) |
| **X3/X3´** | 3.1 (.039) | 3.1 (.039) | 3.2 (.037) | 3.1 (.041) | 3.2 (.036) | 3.1 (.045) | 3.2 (.040) | 3.1 (.052) |

Table 2: P-Values of the comparison (lateral/medial) of the means of different bone parameters in 42 calves. Analysis of Variance with repeated measures.

| **Bone variables/ Factors** | **L/L´** | **X1/X1´** | **X2/X2´** | **X3/X3´** |
|---|---|---|---|---|
| Lateral/Medial | <.0001 | .0002 | <.0001 | <.0001 |
| Hind/Front | <.0001 | <.0001 | <.0001 | .1244 |
| Left/ Right | .2300 | .8010 | .1414 | .0703 |

In most cases X1’ was larger than X1. However, in the value representing the extent of the bone, X2 was larger than X2´. In 82.2 per cent of metacarpal bones, X2 was longer than X2’, in 3.5 per cent, X2’ was longer and in 14.3 percent, the two condyles had the same length.

The measurement X2 was longer in 70.2 per cent, X2` was longer in 4.8 per cent and X2 and X2´were the same in both condyles in 25.0 per cent of the metatarsal bones (Table 3).

Table 3: Comparison of measurements obtained from the lateral and medial aspects of metacarpal and metatarsal bones of 42 calves.

| | Metacarpal bones (n = 84) | Metatarsal bones (n = 84) |
|---|---|---|
| L longer | 44 (52,4 %) | 83 (98,8 %) |
| L` longer | 23 (27,4 %) | 0 |
| L and L´ same length | 17 (21,2 %) | 1 (1.2 %) |
| X1 longer | 19 (22.6 %) | 64 (76.2%) |
| X1´longer | 39 (46.4 %) | 11 (13.1%) |
| X1 and X1´same length | 26 (31.0 %) | 9 (10.7%) |
| X2 longer | 69 (82.2%) | 59 (70.2%) |
| X2´ longer | 3 (3.5%) | 4 (4.8%) |
| X2 and X2´ same length | 12 (14.3%) | 21 (25.0%) |
| X3´ longer | 52 (61.9%) | 72 (85.7%) |
| X3 longer | 12 (14.3%) | 3 (3.3%) |
| X3 and X3´same length | 20 (23.8%) | 9 (11.0%) |

To investigate whether the relationship between the length of the lateral and medial condyles was affected by age, the calves were divided into two groups, one consisting of calves less than 14 days of age (mean 4 days, 0 – 13 days, n = 25) and another consisting of calves older than 13 days (mean 48 days, range 14 – 137, n =

17). The means for X2 and for X2´ were calculated and their differences compared between the two groups.

In the younger calves, the difference between the length of the lateral and medial condyles was 1.1 mm for the left metacarpal bone and 1.0 mm for the right metacarpal bone.

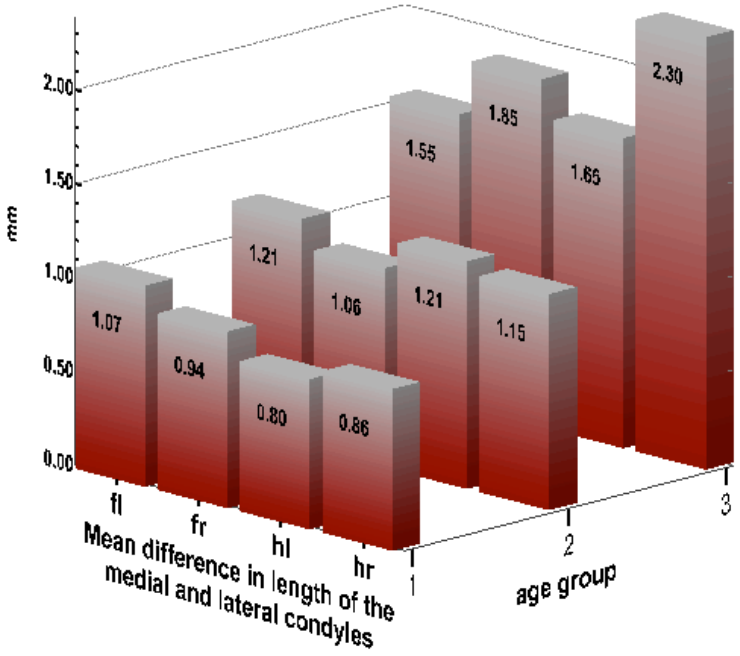


Figure 7: Differences in length (in mm) between the lateral and medial condyles (X2/X2') of the metacarpal/metatarsal bones in cattle of 3 different age groups.

Age group 1 = calves with a mean age of 4 days; Age group 2 = calves with a mean age of 48 days; Age group 3 = cows with a mean age of 44.5 months.
fl = metacarpal bone of the left forelimb, fr = metacarpal bone of the right forelimb, hl = metatarsal bone of left hind limb, hr = metatarsal bone of the right hind limb.

The differences for the left and right metatarsal bones were 0.8 mm and 0.9 mm. In the older calves, these differences were somewhat larger: 1.2 mm for the left metacarpal bone, 1.1 mm for the right metacarpal bone, 1.2 for the left metatarsal bone and 1.2 for the right metatarsal bone.

In the ten cows, the differences between the lateral and medial condyles were 1.6 mm for the left metacarpal bone, 1.8 mm for the right metacarpal bone, 1.7 mm for the left metatarsal bone and 2.3 mm for the right metatarsal bone. Thus, the difference between the lateral and medial condyles appeared to increase with increasing age (Figure 7).

### 5.2 Claw measurements

Table 4: Means of claw variables of 12 calves (96 claws) in centimetres (standard errors in parenthesis). *Obtained by manual measurement

| | **Front** | | | | **Hind** | | | |
|---|---|---|---|---|---|---|---|---|
| **Claw** | **left** | | **right** | | **left** | | **right** | |
| **Variables** | **lateral** | **medial** | **lateral** | **medial** | **lateral** | **medial** | **lateral** | **medial** |
| **Dorsal wall length** | 5.02 (.076) | 5.11 (.073) | 5.00 (.074) | 5.10 (.074) | 5.06 (.097) | 5.15 (.101) | 5.01 (.072) | 5.11 (.072) |
| **Diagonal claw length** | 7.26 (.177) | 7.35 (.188) | 7.30 (.190) | 7.33 (.188) | 6.97 (.149) | 6.96 (.158) | 6.95 (.159) | 6.91 (.170) |
| **Claw width 1** | 2.30 (.072) | 2.25 (.065) | 2.28 (.066) | 2.22 (.058) | 2.26 (.071) | 2.19 (.069) | 2.34 (.075) | 2.18 (.061) |
| **Claw width 2** | 2.91 (.057) | 2.86 (.069) | 2.91 (.067) | 2.86 (.061) | 2.80 (.054) | 2.75 (.062) | 2.81 (.057) | 2.73 (.048) |

The mean values for the claw measurements are shown in table 4. The length of the dorsal wall (DWL) of the medial claw was significantly longer than that of

the lateral claw, both in the front and hind limbs ($p < 0.01$; Table 4; Figure 8).

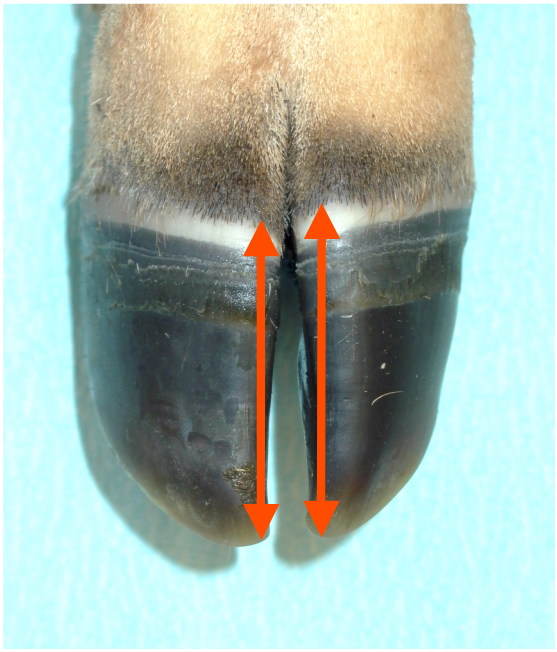

Figure 8: Right hind limb, female Jersey calf, 6 weeks old. The dorsal wall length is greater in the medial claw.

The diagonal length of the claw did not differ between the medial and lateral claws within feet but was significantly larger in the front limbs than in the hind limbs ($p < 0.01$). The mean width of the claw sole at the end of the axial wall (CW1) was significantly larger in the lateral claws than in the medial claws both in the fore and hind limbs ($p < 0.01$). However, this did not apply to all feet; in 14 of the 48 limbs, the width (CW1) of the medial claw was larger, and in 5 limbs, the width of the two claws was the same. The mean width of the claw at the widest part of the sole (CW2) was significantly larger in the lateral claws than in the medial claws both in the front and hind limbs (Table 5).

Table 5: P-Values of different claw parameters, analysis of variance with repeated measures. Significance of differences between lateral and medial claws.

| **Claw variables/ Factors** | **Dorsal wall length** | **Diagonal claw length** | **Claw width one** | **Claw width two** |
|---|---|---|---|---|
| Hind/Front | .4437 | .0005 | .4827 | .0082 |
| Left/Right | .3132 | .6262 | .7476 | >.9999 |
| Lateral/Medial | <.0001 | .3889 | .0029 | .0006 |

The CW2 of the lateral claw of the hind limbs was larger in 11 feet and the same as in the medial claw in 13. In the forelimbs, the lateral claw was wider at CW2 in 11 feet, smaller in one and the same as the medial claw in 12. The comparisons between the feet of the forelimbs and between the feet of the hind limbs did not reveal any differences for CW1 and CW2. There were positive correlations between CW1 and L ($r = 0.30$) and between CW1 and X2 ($r = 0.42$); an increase in length of the lateral condyle was associated with an increase in the width of the sole (CW1). There were no significant correlations between CW2 and L and between CW2 and X2.

## 6. Discussion

The development of methods to measure the cannon bones condyles and claws size seemed to be justified because there could be an important interaction between the condyles' length, the size of the claws and their lesions. The importance of claw size in relation to lameness in cattle is widely recognized.

The primary goal of the present study was to measure the length of the medial and lateral condyles of the metacarpal and metatarsal bones to confirm differences that had been observed previously (Petersen 1921, Paulus and Nuss 2002, Lischer 2000).

There are very few published data about the anatomical characteristics of the metatarsal and metacarpal condyles. Our hypothesis was, that in calves as well as in mature cows, the lateral condyle of the metatarsal bone is longer than the medial condyle and, that in calves the lateral claw is larger than the medial claw. Because, body tissues invariably undergo post mortem changes, only fresh or fresh-frozen specimens were used. However, accurate measurements were difficult in newborn calves, in which the claws were small and the horn soft and pliable. The reliable identification of the same points of measurement on the bones and claws was difficult in some of the specimens.

The difference in the length of the metacarpal and metatarsal bones is thought to be related to the angulations of the hind limb, which functions as lever arm for the propulsion of the body (Frewein et al. 1992).

In the study presented here, a ratio of 1:1,125 for the length of the os metacarpale and metatarsale was calculated, respectively. Frewein et al. (1992) found a ratio of 7:8, which would mean 1:1,142, slightly greater than the ratio of this study.

Our results showed, that the lateral and medial condyles of the metacarpal and metatarsal bones differ in length (Figure 2,3,5), which also confirmed previous limited observations by Petersen (1921). This was already evident in very young calves (Figure 7). So our hypothesis was accepted based on the data of our study. It was surprising that not only in the metatarsal bone, but also in the metacarpal bone, the mean length of the lateral condyle was significantly greater compared with the medial condyle although this did not hold true for every individual foot. The variable X2' which was measured at the condyler ridge that represents the most distally located point of the bone, however was larger than X2 in only three of 84 metacarpal bones and in only four of 84 metatarsal bones. In only a few cases was X2' the same as, or greater than, X2. Because the physis of the metacarpal/metatarsal bones does not represent a straight line (Figure 2), certain inconsistencies in measurements cannot be ruled out. So the lateral condyle, as a rule, is larger than the medial in the Metacarpale as well in the Metatarsale bones. With the exception of the variables X1/X1', the means of the other condylar variables were larger in the lateral condyle compared with the medial condyle. The distance X1' was longer because the physis started higher on the medial side compared to the lateral side (Figure 2 and 4) of the bone. At the level of the joint X1 was more distally in most cases, compared to X'1 (Figure 2).

The difference between the means for X2 and X2' was smallest in the youngest calves and greatest in the cows. Thus, the difference between the mean lengths of corresponding condyles increased with increasing age. However a larger number of feet of each group should be examined to support this finding further.

The mean width of the sole of the lateral claw (CW1 and CW2) of the 12 calves was significantly larger than that of the medial claw in both the front and hind limbs.

In the literature, the medial claw of the bovine front limb is thought to be larger and more weight bearing, on the basis that it is more commonly affected by disease (Toussaint Raven, 1989). Other factors than a difference in length of the condyles may play a role in the development of sole ulcers in the front limbs.

However, the authors of three previous studies determined that in cattle, the sole of the lateral claw of the forelimb was larger than the medial (Fessl,1969; Dämmrich,1982; Schwarzmann, 2004). So the findings of the study presented here are supported.

As well, there was a significant correlation between the width of the claw and the length (X2/X2´) of the ipsilateral metacarpal and metatarsal condyle in our study: The lateral condyle was longer and the lateral claw was wider.

The dorsal wall lengths of the medial claws were significantly larger compared to the lateral claws (Figure 8). This may, to some extent, compensate the difference in length of the condyles. This must be substantiated with a larger number of specimens from cattle of different ages. Of particular interest is whether the difference at the condylar level continues, or even increases, towards the claws, resulting in a difference in length of the two digits. The results of a recent dissertation (Schwarzmann 2004) confirmed this hypothesis.

To conclude, the results of this study led us to accept the hypothesis that in cattle, even in young calves, the medial and lateral metacarpal and metatarsal condyles differ in length and that the lateral condyles are longer than the medial condyles. In a limited number of calves, the lateral claws of the front and the hind limbs were, on average, wider than the medial claws. In the hind limb, there was a positive correlation between the metatarsal condylar length and the width of the claws, the lateral condyle being longer and the lateral claw being wider.

Since it could be substantiated that the difference in length continues to the level of the claws, and that the lateral claws are indeed larger than the medial claws, we might be able to explain why the lateral claw of the hind limb incurs disease more often and more severely than the medial claw.

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## Curriculum vitae

### Personal Details

| | |
|---|---|
| Name | Saidou Nacambo |
| Date of birth | 20.11.1965 |
| Place of birth | Ouahigouya ( Burkina Faso) |
| Nationality | Burkinabe |

### Education

| | |
|---|---|
| 1973 - 1980 | Primary School in Ouahigouya. Exam C.E.P. |
| 1980 - 1990 | High School in Ouahigouya / Ouagadougou. Diplomas B.E.P.C. and Baccalaureat D. |
| 1990 -1997 | Studium in the Veterinary Academy of Moscow (Russia), Diplome of Veterinary Medicine. |
| 1998 - 1999 | Training Period in the Tuileries Veterinary Clinic of Small Animals (Geneva). |
| 1999 - 2001 | Volunteer veterinary surgeon at “Help in Suffering”, Jaipur, India. Medical and surgical care of domestic and exotic species. Street dogs castration and vaccination Programme; Animals Rescue. |
| Since 2002 | Internship at the Vetsuisse Faculty, University of Zurich, Department of Food Animals. |

### Continuing professional Development

February 11 to 15 2004: Attendance of the 13$^{th}$ International Symposium and 5$^{th}$ Conference of Lameness in Ruminants, Maribor (Slovenia).

### Languages

Moore (mother tongue), French, Russian, English, German.